

BIOLOGICAL EFFECTS OF DRILLING FLUID TOWARDS MARINE
ORGANISMS

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Special dedication to my family and my beloved husband for continuous support.

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ABSTRACT

Concern has grown in recent years on the impacts of operational discharges from petroleum exploration and production activities offshore towards marine organisms. When these substances discharge to the ocean, they may persist in the water column and seabed resulting in short-term and long-term effects to the marine environment. Oil based drilling fluid (OBDF) has shown to cause lethal effects and contribute to high mortality towards marine organisms compared to water based drilling fluid (WBDF) and synthetic based drilling fluid (SBDF). Drilling fluid and its components may induce histological alterations to the tissues and organs of marine life, which in turn lead to the death of organisms as a result of organ structural and functional impairment. Field studies on benthic communities demonstrated that the biological effects of OBDF were more severe compared to WBDF and SBDF which include changes in species diversity, abundance and alterations to community structure. The extend of OBDF effects was longer and occurred in the range of 500 to 1,000 m or even more. While WBDF and SBDF were minor and localized in the range of 50 to 250 m. The effects are mainly due to physical changes and natural processes irrespective of the type of drilling fluid. Biological effects due to petroleum-related activities are mostly seen if elevated oil concentration is present. As a conclusion, drilling fluid must be carefully designed and formulated to lessen the biological impact to marine life. WBDF and SBDF shall be used whenever possible but proper and less toxic chemicals need to be carefully chosen during formulation. OBDF shall be prohibited and replaced with a more environmentally acceptable SBDF to minimize the biological effects to marine life.

ABSTRAK

Beberapa tahun kebelakangan ini, pelepasan sisa daripada aktiviti penerokaan petroleum di pesisir telah memdatangkan kebimbangan tentang kesan aktiviti ini kepada organisma marin. Ini kerana, apabila bahan-bahan tersebut dilepaskan ke laut, bahan tersebut mungkin kekal di dalam atau dasar laut, menyebabkan kesan buruk jangka pendek dan panjang kepada persekitaran laut. Cecair penggerudian berasaskan minyak (OBDF) telah terbukti menyebabkan kesan yang buruk dan menyebabkan kematian organisma marin berbanding cecair penggerudian berasaskan air (WBDF) dan sintetik (SBDF). Cecair penggerudian dan komponennya juga boleh menyebabkan perubahan histologi kepada tisu dan organ organisma, yang seterusnya membawa kepada kematian organisma tersebut disebabkan oleh kegagalan struktur dan fungsinya. Kajian lapangan di komuniti bentik telah menunjukkan bahawa kesan biologi daripada OBDF adalah lebih teruk berbanding WBDF dan SBDF, termasuklah perubahan dalam kepelbagaian, jumlah dan struktur spesies. Kesan biologi daripada OBDF berlanjutan lebih lama dan berlaku di antara 500 hingga 1,000 m, manakala SBDF dan WBDF terhad di kawasan 50 hingga 250 m daripada tapak penggerudian. Pengurangan jumlah spesies di kawasan yang terlibat adalah disebabkan oleh kesan fizikal atau semula jadi tanpa mengira jenis cecair penggerudian yang digunakan. Kesan biologi yang disebabkan oleh aktiviti berkaitan petroleum dilihat terjadi di kawasan kepekatan minyak yang tinggi. Kesimpulannya, cecair penggerudian perlulah dipilih dan direka dengan teliti bagi mengurangkan kesan biologi terhadap kehidupan marin. WBDF and SBDF hendaklah digunakan jika bersesuaian tetapi pemilihan bahan kimia yang kurang toksik perlu diambil kira semasa formulasi. Penggunaan OBDF perlu dilarang dan digantikan dengan SBDF yang lebih mesra alam bagi mengurangkan kesan biologi terhadap organisma marin.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	SUPERVISOR'S DECLARATION	ii
	TITLE PAGE	iii
	STUDENT'S DECLARATION	iv
	DEDICATION	v
	ACKNOWLEDGEMENTS	vi
	ABSTRACT	vii
	ABSTRAK	viii
	TABLE OF CONTENTS	ix
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Problem Statement	2
	1.3 Objectives	3
	1.4 Scopes of Project	4
2	LITERATURE REVIEW	5
	2.1 Overview of Drilling Fluid	5
	2.2 Functions of Drilling Fluid	6
	2.3 Types of Drilling Fluid	7

2.3.1	Water Based Drilling Fluid (WBDF)	8
2.3.2	Oil Based Drilling Fluid (OBDF)	9
2.3.3	Synthetic Drilling Fluid (SBDF)	10
2.3.4	Pneumatic Based Drilling Fluid	11
2.4	Composition of Drilling Fluid	12
2.5	Drilling Fluid and Cuttings Discharges	16
3	METHODOLOGY	19
3.1	Problem Formulation	20
3.2	Data Collection	20
3.3	Data Evaluation	21
3.4	Data Analysis and Interpretation Stage	21
3.5	Writing the Literature Review	21
4	TOXICITY EFFECTS OF DRILLING FLUID TOWARDS MARINE ORGANISMS	23
4.1	Toxicity Effects of Drilling Fluid Ingredients Towards Marine Organisms	24
4.2	Toxicity Effects of the Whole Drilling Fluid Towards Marine Organisms	26
4.3	General Discussion	30
5	BIOLOGICAL EFFECTS OF DRILLING FLUID TOWARDS MARINE ORGANISMS	32
5.1	Histological Effects OF Drilling Fluid towards Marine Organisms	32
5.1.1	Effects of Drilling Fluid to Respiratory Organ	33

5.1.2	Effects of Drilling Fluid to Liver Organ	38
5.1.3	Effects of Drilling Fluid to Reproduction Organ	40
5.1.4	Effects of Drilling Fluid to Other Organs	42
5.1.5	General Discussion	43
5.2	Field Observation on the Biological Effects of Drilling Fluid Exposure to Benthic Environment	47
5.2.1	Effects of WBDF to Benthic Communities	47
5.2.2	Effects of OBDF to Benthic Communities	51
5.2.3	Effects of SBDF to Benthic Communities	53
5.2.4	General Discussion	55
6	CONCLUSION AND RECOMMENDATION	58
6.1	Conclusion	58
6.2	Recommendation for Further Research	59
	REFERENCES	60
	APPENDICES	68

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Comparison of the Concentrations of Metals In Typical WBDF and OBDF Fluid	14
2.2	Summary of Drilling Fluid Composition	15
2.3	The Amount of Drilling Fluid Components Discharged From Offshore Drilling Operations in 1998	18
3.1	Defining the Types Of Sources For a Review	20
4.1	Acute Toxicity of Major Italian Drilling Fluid Products	26
4.2	Toxicity Rating Classification System	29
4.3	Revised Marine Water Column Toxicity Classification	30
5.1	Composition of Drilling Fluid - (Parateq)	42
5.2	Summary of Histological Effects of Drilling Fluid Towards Marine Organisms	45
5.3	Summary of Effects nn Species Due to Petroleum and Individual PAH	46
5.4	The Zones of Effect of OBM Cuttings Based Upon Wide Range of Surveys around North Sea Oilfield	51
5.5	Levels of Hydrocarbon Contamination That Affect Macrobenthic Indicators	54
5.6	Summary of Field Observation on Benthic Communities	57

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Hierarchical Row of Pollutant Exposure within Biological System	3
2.1	Types of Drilling Fluid	8
2.2	Water and Oil Based Drilling Fluid Composition	12
2.3	Dispersion and Fates of Drilling Fluid Following Exposure to the Ocean	17
5.1	Pathway of Hydrocarbon Exposure and Metabolism in Fish	33
5.2	(a) Schematic of the Teleost Fish Gill	34
	(b) Schematic of Internal Anatomy of Suspension Feeder, clam	34
	(c) Schematic of Internal Anatomy Crustaceans, Shrimp	35
5.3	Overview of the Hormonal of Egg Development (oogenesis) in Fish	40
5.4	Pictures of <i>Umbellula</i> colonies	49
5.5	Change in Total Abundance of Species	50
5.6	Maximum and Minimum Extend of Increases of Decreases In Physical and Biological Variables From the Drill Dites Relative to the Background Levels	52

LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
Ba	-	Barium
BaSO ₄	-	Barium Sulfate
Ca(OH) ₂	-	Calcium Hydroxide
ELG	-	Effluent Limited Guideline
EPA	-	Environmental Protection
GESAMP	-	Joint Group of Experts On The Scientific Aspects Of Marine Environmental Protection
KOH	-	Potassium Hydroxide
LC	-	Lethal Concentration
NaOH	-	Sodium Hydroxide
OBDF	-	Oil Based Drilling Fluid
PAH	-	Polynuclear Aromatic Hydrocarbon
POA	-	Polyalphaolefin
SBDF	-	Synthetic Based Drilling Fluid
SPP	-	Suspended Particle Phase
THC	-	Total Hydrocarbon Content
TPH	-	Total Petroleum Hydrocarbon
WSF	-	Water Soluble Fraction
WBDF	-	Water Based Drilling Fluid

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	RTE Drilling Fluid Products	68
B	Summary of Acute Toxicities of WBDF Ingredients To Marine Algae and Animals	71
C	Ingredients Used in Formulation for Drilling Mud	72
D	Ingredients Used in Formulation for Drilling Mud XP-07 Synthetic-based Drilling Fluid Product Sheet	73
E	The Concentration of Total Oil Related to the Distance From Platform & Species Diversity	74
F	Relative Abundance of Meiofauna Samples	75

CHAPTER 1

INTRODUCTION

1.1 Introduction

The oceans, which cover more than 70 percent of the earth, play important roles in maintaining the world's sustainability and are the final recipient for many wastes. One of the sources for ocean contamination is from drilling fluids that are used extensively in the upstream of oil and gas drilling industry. Drilling fluids are a complex mixture containing various types of additives and chemicals such as corrosion inhibitors, lubricants and surfactant to enhance the technical performance during drilling operation. Drilling fluids serve many functions which include to remove drill cuttings to the surface for disposal, cool and lubricate the drill bit, maintain downhole hydrostatic pressure, reduce friction in the borehole and many more (Soegianto *et al.*, 2008; Ismail *et al.*, 2014).

Despite their vital roles, the discharges of drilling fluid and cuttings produced during drilling process have shown to have undesirable effects to the local marine environment (Saliu and Salami, 2013). These have raised public concerns on the effects of drilling fluid and its additives, thus many countries have introduced regulations and restrictions regarding the disposal of drilling waste to the environment. This is because, drilling fluid and its additives may contain toxic substances that have the tendency to bioaccumulate and interfere with normal organisms biological activities. Most research

to date has focused on the toxic effects of drilling fluid. Limited studies are available on the biological effects of drilling fluid towards marine organisms.

1.2 Problem Statement

There is an increasing concern about the impacts on marine organisms by drilling fluid and cuttings discharges from petroleum and exploration activities offshore. Many studies in the past have investigated on the toxicity of drilling fluid and its components towards marine life (Ismail *et al.*, 1997; Neff, 2005; Soegianto *et al.*, 2008; Bakke *et al.*, 2013; Ismail, 2014). The toxicity studies have shown highest mortality rate in animals following exposure to OBDF compared to WBDF and SBDF. Apparently, there is a general shortage of knowledge about potential biological effects of drilling fluid and cuttings released during these operations to the local marine organisms. It may be questioned whether the mortality are related to the toxicity of the drilling fluid base, its individual components or mainly physical effects due to the accumulation of particles.

These animals ingest the toxic substances through their diet, metabolize it in the liver and absorb it through their gill. In order to understand the relationship between the toxicity and biological effects of drilling fluid towards marine life, further studies on what actually causes the animals to die need to be conducted. An adverse effect of drilling fluid may be considered as a sequential row of disorder going from the molecular level and up to higher hierarchical levels of biological organization (Figure 1.1). Subsequently, short-term biological responses can be seen in changes at the molecular level which then proceeded by long term impacts on the population. It may also be disputed whether the field surveys have the same responses as the laboratory works, thus it is important to discuss and analyze the potential biological effects for both cases to further understand the impact of drilling fluid to the animal's biological system. This review might be helpful in selection of drilling fluids and additives to limit its environmental impacts on marine organisms.

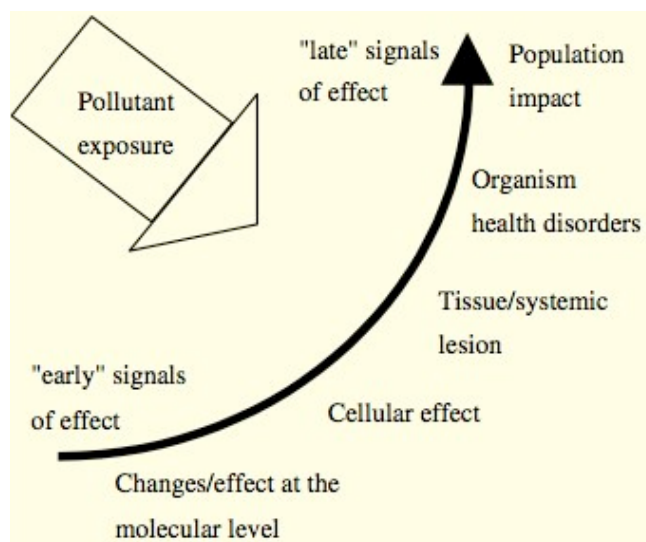


Figure 1.1: Hierarchical Row Of Pollutant Exposure Within Biological System (Beyer *et al.*, 2001)

1.3 Objectives

The objectives of this project are as follows:

- 1) To identify the toxicity effects of drilling fluid and its component towards marine organisms.
- 2) To identify any histological alteration induced in the tissues and organs following exposure to drilling fluid and its components.
- 3) To identify potential biological effects of drilling fluid and cuttings towards benthic environment.

1.4 Scopes of Project

The scopes of this review are as follows:

- 1) To evaluate several laboratory study cases on the level of toxicity effects of different drilling fluid type including potential toxic chemicals towards marine organisms and it's the relation to mortality.
- 2) To evaluate the mechanism of action of drilling fluid and its components that may have caused histological alteration in the tissue and organs.
- 3) To evaluate whether histological alteration cause any structural and functional damage to the organs.
- 4) To discuss potential biological effects, the nature and extend of exposure of drilling fluid and cuttings towards marine communities based on several study cases.
- 5) To evaluate whether the effects are related to drilling fluid and cuttings or natural processes.

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